Dual-Energy X-ray Absorptiometry and Bioelectrical Impedance Analysis are Beneficial Tools for Measuring the Trunk Muscle Mass of Patients with Low Back Pain

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Abstract:

Introduction: Limb muscle mass measurement using dual-energy X-ray absorptiometry (DXA) is considered the gold standard for the diagnosis of sarcopenia. Moreover, bioelectrical impedance analysis (BIA) is also recognized as a beneficial tool considering its high correlation with DXA. However, it remains to be elucidated whether DXA and BIA can accurately measure trunk lean mass.

The aim of this study was to investigate the correlation between DXA and BIA measurements of trunk muscle mass and the cross-sectional area (CSA) of trunk muscles measured using magnetic resonance imaging (MRI) and to compare measures of trunk muscle mass obtained using DXA and BIA in patients with low back pain (LBP).

Methods: In total, 65 patients participated in the study. The correlation between DXA and BIA measurements and the CSA of trunk and paraspinal muscles at the L4-5 level were calculated. In addition, the correlation between DXA and BIA measurements of trunk muscle mass and the differences between these two measurements were determined.

Results: The correlation coefficient between DXA and BIA trunk muscle mass measurement and trunk muscle CSA was 0.74 and 0.56 for men and 0.69 and 0.44 for women, respectively. DXA and BIA measurement values showed a significantly moderate correlation with the CSA of the erector spinae (ES) and psoas major (PM). The multifidus (MF) CSA did not correlate with measurements of DXA and BIA in both men and women. Although DXA and BIA measurements were significantly correlated, a significant difference between these two measurements was found. BIA overestimated the trunk muscle mass significantly compared with DXA.

Conclusions: Trunk muscle mass measured with DXA and BIA was correlated with the CSA of most trunk muscles. Although the measurement of DXA and BIA showed a high correlation, BIA overestimated trunk muscle mass compared with DXA. Both DXA and BIA are beneficial for measuring trunk muscle mass.

Introduction

As a recent topic in an aged society, sarcopenia has received attention as a factor of deterioration in motor function in elderly individuals, leading to the development of various studies. Limb muscle mass measurement using dual-energy X-ray absorptiometry (DXA) is considered as the gold standard for the diagnosis of sarcopenia[1]. In addition, bioelectrical impedance analysis (BIA), which measures body composition and is frequently used in clinical settings in recent years, has a high correlation with DXA in limb muscle mass measurement. A previous study has showed its use in patients with low back pain (LBP)[2].

On the contrary, it remains to be elucidated whether trunk lean mass measured using DXA and BIA reflects actual trunk muscle mass. Thus, it is necessary to estimate trunk muscle mass from its cross-sectional area (CSA) in magnetic resonance imaging (MRI) or computed tomography (CT). Currently, there is no validated method to measure actual trunk muscle mass. Therefore, trunk muscle mass is frequently not included in the diagnostic criteria for sarcopenia[1,3,4]. By contrast, measuring the CSA of these muscles presents some limitations: it is time-consuming, MRI and CT are expensive and require dedicated facilities, and the risk of radiation exposure in the case of CT cannot be ignored. These factors limit the use of these tests in clinical practice.

Recent studies have found paraspinal muscle atrophy and fatty degeneration in elderly patients with kyphosis[5,6]. However, there have been no reports on whether trunk lean mass measurement by DXA or BIA is as valid as in the evaluation of limb muscle mass.

Thus, this study was performed with the following objectives: First, to determine the correlation between DXA and BIA measures of trunk muscle mass and the CSA of these muscles. Second, to determine the individual muscles that present a larger correlation. Third, to determine the correlation and differences between DXA and BIA measurements of trunk muscle mass.

Materials and Methods

This cross-sectional study was approved by our hospital's Ethics Review Committee and informed consent was obtained from all the study participants. We enrolled patients admitted to our outpatient department with LBP as the chief complaint, regardless of the cause, during a 21-month period from April 2015 to December 2016.

The participants underwent DXA and BIA body composi-

tion measurements and lumbar spine MRI.

The following were the exclusion criteria: (1) patients with difficulty standing upright because of pain, paralysis, or spinal kyphosis; (2) patients with cardiac pacemaker; (3) obese patients (body mass index > 30 kg/m^2); (4) patients with artificial joints/spinal implants in the limbs and trunk.

DXA (Discovery; Hologic, Waltham, MA, USA), BIA (MC-780A, TANITA, Tokyo, Japan), and 1.5T MRI (Signa HDxt 1.5T, GE healthcare, Waukesha, WI, USA) were performed with the same device for all patients within our facility. Measurement intervals with each measuring instrument were set to within 1 month.

Limb and trunk muscle masses were evaluated from the body composition data obtained from DXA. Trunk muscle mass was determined through the value of fat-free mass in the body regions excluding head and limbs (Fig. 1). BIA is a noninvasive examination technique used for evaluating bone mass, fat mass, and fat-free mass by flowing weak currents with three different frequencies (5, 50, and 250 kHz) using 8 electrodes in total, 2 for each sole and grip in standing barefoot position, and determining the difference in electric resistance. The analysis time is less than 20 s. Limb and trunk muscle masses were determined directly from the value of lean mass provided by the device. The muscle mass measured by the device is the tissue volume excluding fat and bone mass calculated based on the measurement value of DXA. Therefore, it is a value including skeletal muscle, smooth muscle (internal organs), and body water content. The body weight was also measured by this device to the closest 100 g and a maximum weight of 300 kg. Although there is a possibility that a weight difference may occur between the two measurement periods (DXA and BIA), we assumed that the difference was not meaningful in this study. Measurement time was assumed to be the fasting state before lunch so as not to be affected by meals. We calculated the skeletal muscle mass index obtained by dividing the limb muscle mass by height squared from DXA- and BIA-based measures of limb muscle mass.

MRI scans were stored in DICOM format using 1.5T MRI. We used the axial image from the preoperative MRI to L4-5 level T2-weighted image (repetition time/echo time = 3000-5000 ms/90-100 ms).

The axial image was aligned parallel to the lower end plate of the L4 vertebral body. We measured the CSA by constructing polygonal points around the outer edges of the paraspinal muscles (multifidus, MF; erector spinae, ES; psoas major, PM). The number of points selected for each image varied according to muscle shape and size; the generated polygon reflected the muscle shape. We calculated the
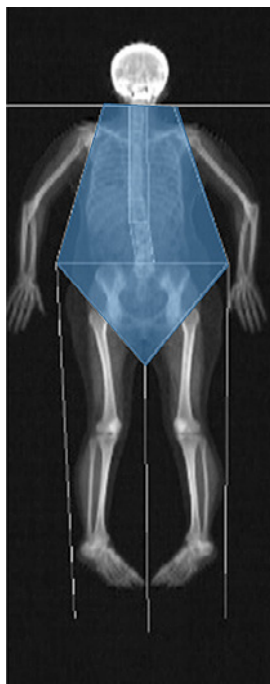
Figure 1. DXA imaging.
We defined trunk fat-free mass, excluding the head and limbs, as trunk muscle mass.

Figure 2. Magnetic resonance imaging.
We measured paraspinal muscle cross-sectional area at the L4-5 level.
MF, multifidus; ES, erector spinae; PM, psoas major

area inside the polygon by using the Reformat function installed in the MRI console (Fig. 2).
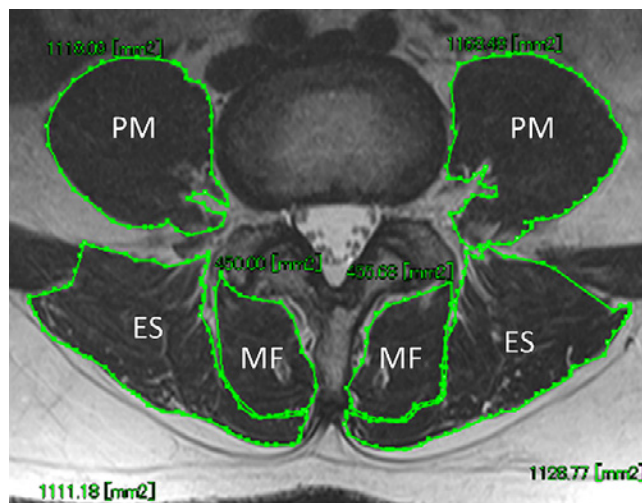
The sum of the CSA of MF, ES, and PM was calculated (mm^2) and defined as the CSA of trunk muscles.

Three spinal surgeons performed all measurements three times each, and the average value was used. Measurement intervals were set at least with a 2-week interval.

After data collection, we performed three analyses: 1) correlation between the measurements of DXA and BIA, and trunk muscle CSA at the L4-5 level; 2) correlation between the measurements of DXA and BIA, and the CSAs of individual paraspinal muscles at the L4-5 level; 3) correlation between DXA and BIA measurements of trunk muscle mass, and differences between these two measurements.

Statistical analysis

All measurements were evaluated separately for men and women. Correlations were evaluated using Spearman rank correlation coefficient. Pairwise differences between DXA and BIA measurements were examined using the *t*-test. The level of significance was set at 0.05 for all tests. The normality of each measured value was tested at a risk rate of 5%. We evaluated the intraexaminer reproducibility and the interexaminer reliability by using one-way analysis of variance (ANOVA). We evaluated the intraexaminer reproducibility by calculating the intraclass correlation coefficient (ICC) from the three measurements obtained by each examiner. In addition, we calculated the ICC with a 95% confidence interval (CI) by comparing the average of the three results of the three examiners and evaluated the interexaminer reliability.

All analyses were performed using JMP Pro version 12 (SAS Institute Inc., NC, USA).

Results

Patient characteristics

A total of 65 patients (women, 35; average age, 64.6 ± 13.5 years) participated in the study. The patient characteristics are summarized in Table 1. Of these patients, there were no patients receiving dialysis, because the results could be affected by water intake.

Correlation between DXA and BIA measurements of DXA and BIA and trunk muscle CSA at the L4-5 level

The correlation coefficient between the DXA measurement and trunk muscle CSA was 0.74 for men (p < 0.0001) and 0.69 for women (p < 0.0001); for the BIA measurement, the correlation coefficient was 0.56 for men (p = 0.002) and 0.44 for women (p = 0.009).

DXA and BIA measurements were significantly correlated with the trunk muscle CSA in both men and women (Fig. 3).

Correlation between DXA and BIA measurements and the CSAs of individual paraspinal muscles at the L4-5 level

DXA measurements showed a significantly moderate correlation with the CSA of ES and PM in both men and women. BIA measurements showed the same tendency. The CSA of MF did not correlate with DXA and BIA measurements in both men and women (Table 2).

Table 1. Patient Characteristics.

	Men (n=30)	Normality, p value	Women (n=35)	Normality, p value
Age, years	63.9±13.6	0.1	65.2±13.6	0.02*
Height (m)	1.68±0.06	0.7	1.52±0.07	0.1
Weight (kg)	65.0±12.9	0.7	51.2±11.2	0.2
BMI (kg/m^2)	23.1±3.7	0.3	22.0±4.2	0.4
Limb muscle mass (DXA) (kg)	20.4±3.7	0.06	13.1±2.7	0.02*
DXA-based SMI (kg/m^2)	7.2±1.0	0.4	5.6±1.0	0.03*
Limb muscle mass (BIA) (kg)	22.7±4.3	0.4	14.9±2.6	0.06
BIA-based SMI (kg/m^2)	8.0±1.2	0.01*	6.4±1.0	0.3
Trunk muscle mass (DXA) (kg)	23.3±3.6	0.4	16.9±3.0	0.08
Trunk muscle mass (BIA) (kg)	26.9±3.2	0.4	19.2±2.9	0.06
Trunk muscles' CSA (mm^2)	6690.6±1313.3	0.2	4628.3±1017.1	0.6
MF CSA (mm^2)	905.5±508.6	0.3	368.1±208.0	0.009*
ES CSA (mm^2)	3235.9±1056.5	0.3	2716.9±914.4	0.1
PM CSA (mm^2)	2549.2±526.6	0.3	1543.3±331.4	0.07

The values are given as mean±SD.

*p value <0.05; not normally distributed

BMI, body mass index; SMI, skeletal muscle mass index; DXA, dual-energy X-ray absorptiometry; BIA, bioelectrical imped-ance analysis; CSA, cross-sectional area; MF, multifidus; ES, erector spinae; PM, psoas major

Figure 3. Correlation between DXA and BIA measurements of DXA and BIA and trunk muscle cross-sectional area at the L4-5 level.

Correlation between DXA and BIA measurements of trunk muscle mass, and differences between these two measurements

The correlation coefficient between DXA and BIA measurements was 0.77 for men (p < 0.0001) and 0.54 for women (p = 0.002).

The mean values of trunk muscle mass measured with DXA were 23.3 ± 3.6 kg for men and 16.9 ± 3.0 kg for women. BIA mean values of trunk muscle mass were 26.9 ± 3.2 kg for men and 19.2 ± 2.9 kg for women.

Differences between these two measurements (BIA minus DXA) were 3.6 ± 0.45 kg for men (p < 0.0001) and 2.3 ± 0.45 kg for women (p < 0.0001). BIA seemed to signifi-

cantly overestimate the trunk muscle mass compared with DXA (Fig. 4).

Both the intraexaminer reproducibility and interexaminer reliability were excellent (Table 3).

There was no significant correlation between BMI and differences between DXA and BIA measurements of trunk muscle mass (Table 4). Therefore, for both men and women, BMI values less than 30 did not affect the difference be-

tween BIA and DXA measurements.

Discussion

In the present study, we found that DXA and BIA measurements were significantly correlated with trunk muscle CSA at the L4-5 level. DXA measurements correlated significantly with ES and PM CSA, but not with the MF CSA. BIA measurements showed the same pattern.

DXA and BIA measurements were significantly correlated in both men and women, but BIA overestimated the trunk muscle mass compared with DXA.

As previously described, it is still unclear whether trunk lean mass measured using DXA and BIA can adequately measure the actual trunk muscle mass. Trunk muscle mass is generally estimated from its CSA using MRI or CT, and its efficacy has been shown in past studies[5,6]. We frequently perform MRI in patients presenting with LBP as a chief complaint. However, it is not a feasible method of assessing trunk muscle CSA in clinical settings because of the time and effort associated with its execution. A CSA decrease is thought to indicate a decrease in muscle mass caused by muscle atrophy[7,8]. Because the measurements of DXA and BIA correlated with trunk muscle CSA, these two methods seem to reflect trunk muscle mass.

DXA measurements correlated significantly with ES and PM, but did not correlate with MF. BIA measurements also

Table 2. Correlation between DXA and BIA Measurements and the CSAs of Individual Paraspinal Muscles at the L4-5 Level.

		Men		Women	
		DXA	p value	DXA	p value
CSAs	MF	−0.18	0.32	0.15	0.4
	ES	0.62*	0.0009	0.61*	0.0003
	PM	0.48*	0.01	0.63*	0.0003
		BIA	p value	BIA	p value
	MF	−0.01	0.9	0.20	0.3
	ES	0.35	0.06	0.37*	0.03
	PM	0.52*	0.005	0.33	0.06

*p value <0.05; statistically significant

DXA, dual-energy X-ray absorptiometry; BIA, bioelectrical impedance analysis; CSA, cross-sectional area; MF, multifidus; ES, erector spinae; PM, psoas major
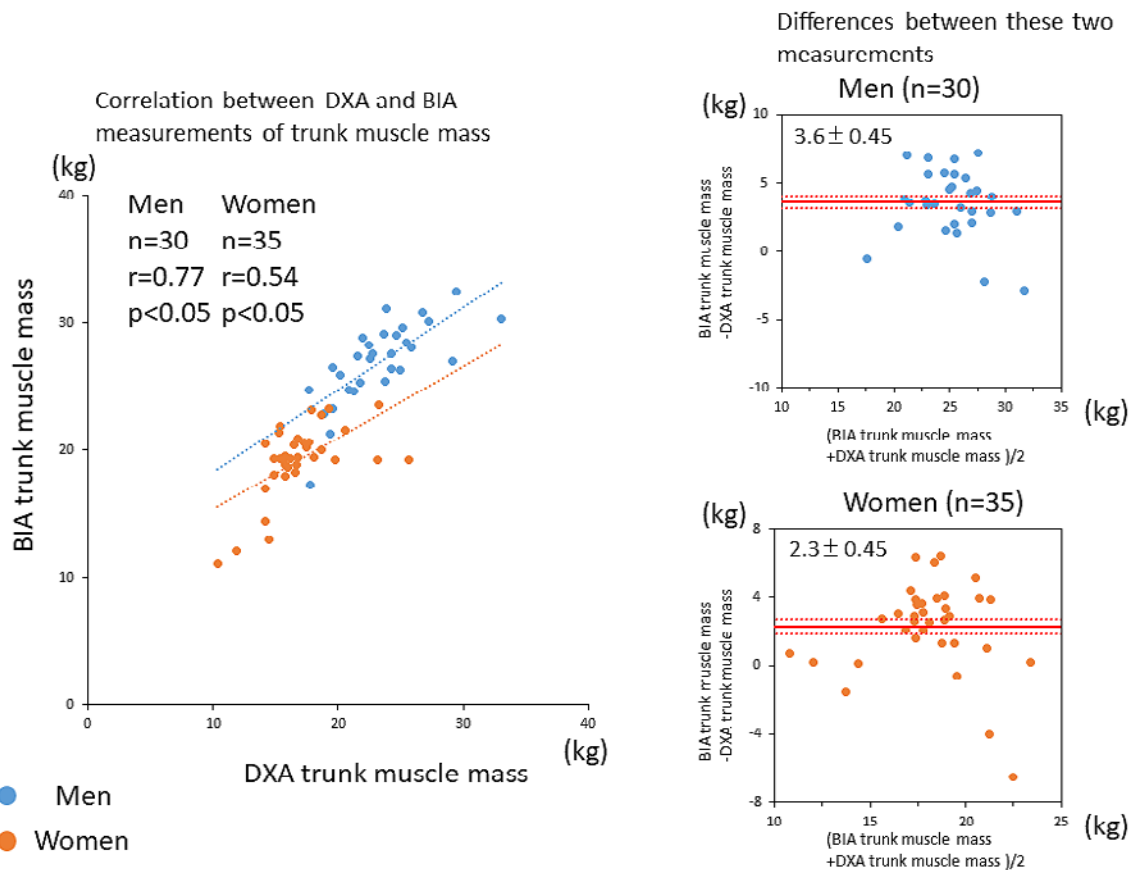
Figure 4. Correlation between DXA and BIA measurements of trunk muscle mass, and differences between these two measurements.

Table 3. Intraexaminer Reproducibility and Interexaminer Reliability.

	Intraclass correlation coefficient	
	Intraexaminer	Interexaminer
MF	98.70-99.99	97.87-98.82
ES	99.28-99.41	99.10-99.24
PM	98.49-99.46	99.22-99.34

MF, multifidus; ES, erector spinae; PM, psoas major

Table 4. Correlation between BMI and Differences between DXA and BIA Measurements of Trunk Muscle Mass.

	Correlation coefficient (r)	p-value
Men	−0.20	0.3
Women	−0.13	0.5

p-value <0.05; statistically significant
BMI, body mass index; DXA, dual-energy X-ray absorptiometry; BIA, bioelectrical impedance analysis

showed the same tendency. Previous studies have reported that PM CSA measured using CT imaging correlates with the limb muscle mass measured using BIA[9], but there is no evidence of such a correlation with trunk muscle mass. In this study, we demonstrated a positive correlation of trunk muscle mass with not only the CSA of PM but also the CSA of ES. However, trunk muscle mass showed no correlation with the CSA of MF. It has been previously reported that fatty degeneration of MF causes LBP and lumbar spine dysfunction[10,11]. Considering this fact, it would seem many of our study participants have fatty degeneration of MF. Thus, the degree of MF degeneration is not reflected in DXA and BIA measurements of trunk muscle mass.

The measurement of DXA correlated with the measurement of BIA in both men and women, whereas BIA overestimated the trunk muscle mass compared with DXA. According to previous reports comparing DXA and BIA measurements of limb muscle mass, the two methods show a high correlation[12], but BIA tends to provide an overestimation[13]. In agreement with previous research regarding limb muscle mass measurement, DXA and BIA showed a high correlation in patients with LBP, but BIA overestimated limb muscle mass compared with DXA[2]. It has been reported that trunk muscle mass is also overestimated in BIA compared with DXA in healthy subjects[13]. The same result was also found when measuring trunk muscle mass in patients with LBP in this study. DXA measurement is performed with the patient in the supine position, and BIA measurement is performed with the patient in the standing position. Because body moisture moves to the lower extremities when standing up from the spine position, it is desirable that BIA measurement should be performed in a state where moisture is stable after at least 20 min or more in standing or sitting position. In this study, BIA measurements were performed at outpatient visits, and we assumed that the body water distribution of all patients was stable and was suitable for BIA measurement.

Paraspinal muscle atrophy has been found to be involved in the pathogenesis of LBP[5,6]. The present study showed the benefits of DXA and BIA for measuring trunk muscle mass in patients with LBP. The current results open the possibility of using DXA and BIA as a routine measurement of trunk muscle mass in LBP examination.

To determine the CSA measurement level, we considered the following. At the upper lumbar levels, the CSA of PM becomes smaller. At the lower lumbar levels, the CSA of the trunk muscles becomes larger, but at the L5-S1 level, the CSA of ES is affected by the ilium. Thus, we decided to measure the CSA at the L4-5 level. In the past literature comparing trunk muscles between patients with degenerative lumbar kyphosis and healthy control subjects, changes in MF and ES were considered to have a significant difference only at the lower lumbar level, where their CSA was larger[5].

This study has some limitations. First, patients with artificial joints/spinal implants, who are often seen in orthopedic outpatient settings, were excluded from the study. Second, patients with degenerative scoliosis, who frequently present with difficulty in standing and LBP, were also excluded. Third, there was no control group of healthy subjects. Pain in patients with LBP may result from atrophy of the MF muscle, which may have influenced the study results.

In this study, trunk muscle mass measured using DXA and BIA was correlated with the CSA of the paraspinal muscles, especially PM and ES. Although the measurement of DXA and BIA showed a high correlation, BIA overestimated trunk muscle mass compared with DXA. Both DXA and BIA are useful for measuring trunk muscle mass. These evaluation methods may become a powerful tool for the measurement of trunk muscle mass as part of a comprehensive LBP screening in the future.

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